

A novel DC current transformer using magneto-resistance sensors for FAIR

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A Novel DC Current Transformer (N-DCCT) for FAIR SIS100 is under development at GSI Beam Diagnostic department in collaboration with IES Institute of TU Darmstadt. DCCTs are used as non-intercepting standard tools for online beam current measurement in synchrotrons and storage rings. The working principle of commonly used DCCTs is well known [1]. However, at certain bunch frequencies in ring accelerators inaccurate readings are observed due to inter-modulation distortion. The N-DCCT senses the magnetic field created by the ion beam current, using Tunneling Magneto-Resistance (TMR) sensors. Also a closed-loop N-DCCT is currently under development.

TMR Sensor for N-DCCT

Currently a N-DCCT based on TMR sensors is under development at GSI. The N-DCCT open-loop structure is shown in Figure 1 [2]. The main measurement principle is precise detection of the ion beam DC magnetic field by TMR sensors. In the present setup the TMR sensors from MultiDimension Company [3] are placed inside an air gap of a high permeability ferromagnetic ring core with 10 mm width (VITROVAC '6025F'). The value of the magnetic field inside the air gap is calculated according to the following formula:

$$B_{\text{gap}} = \frac{\mu_0}{d} I_P \quad (1)$$

Where B_{gap} is the magnetic field inside the air gap in Tesla, μ_0 is the permeability of vacuum in Tm/A, I_P is the beam current and d is the air gap width in m.

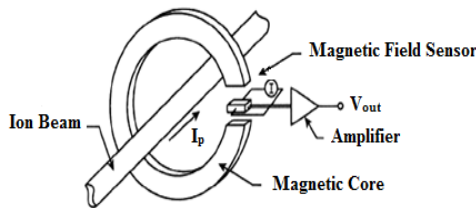


Figure 1: N-DCCT Open Loop Structure.

The TMR's output voltage is directly proportional to the ion beam current. A voltage amplifier is added to enhance the N-DCCT resolution. Printed circuit boards were fabricated to compare the performance of different MR sensors. A test setup has been prepared for the N-DCCT as shown in Figure 2. A mechanical support was manufactured to hold the flux concentrator. In addition a μ -metal box for shielding covers the whole N-DCCT test setup.

A DC current is generated in a conducting wire at the center of the core using a power amplifier and a signal generator. The value of the produced voltage from the power amplifier is $\pm 32\text{V}$. This will produce a $\pm 0.32\text{A}$ in the wire. The value of the magnetic field intensity in the air gap of the core will be $\pm 0.04\text{mT}$. The output voltage of the TMR sensors is amplified with a voltage amplifier of gain 10.

Tests were carried out for two different TMR sensors, MMLH45F and MMLP57F. Figure 3 shows the output voltage of the N-DCCT versus input current for the MMLH45F. The slope of transfer characteristic is the sensitivity of the N-DCCT. The measured value from the experimental test is 0.566V/A , while the theoretical value is 0.75V/A . The sensitivity of the TMR sensor to the magnetic field is 0.453V/mT from the measurements and 0.6V/mT from the sensor's datasheet. Measurements with the sensor type MMLP57F yielded a sensitivity of 0.275V/A , compared to 0.31V/A (datasheet). The noise analysis for the system is currently under investigation.

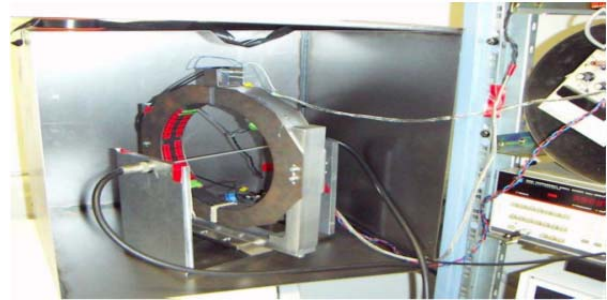


Figure 2: N-DCCT Test Setup.

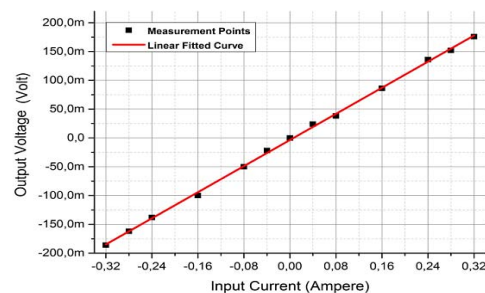


Figure 3: Output Voltage of the N-DCCT.

References

- [1] K. Unser, "A Toroidal DC Beam Current Transformer with High Resolution", IEEE Trans. Nuclear Science, NS-28 No. 3, June 1981
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